



# Status of Temporary Wetland of Paddy Field Associated Molluscs of Coastal Karnataka: A Case study

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**Abstract:** Freshwater molluscs contribute to the ecosystem by increasing soil fertility and nutrient cycling. The study was designed to estimate the diversity and abundance of molluscs from the coastal paddy fields of Karnataka state of India. Six paddy fields of Karnataka state were selected for the study from June-November 2017 and 2018 whereas the paddy field of Marlimar was surveyed from June 2017-April 2018, June 2018-March 2019 as the paddy cultivation occurs up to two cropping cycles. Presence of *Idiopoma dissimilis*, *Indoplanorbis exustus*, *Physella acuta*, *Pila virens* and *Racemina luteola* was observed from paddy fields. *P. virens* and *I. exustus* were in most of the paddy fields of coastal Karnataka. Abundance of snails increased in the initial months of cropping and declined towards the harvest of the paddy. Snail diversity was highest in the paddy field of Marlimar and least in Mattu. pH of water ranged between 3.54 and 8.53, Electrical conductivity 3.89-1136 $\mu$ S/m, soil pH 3.07-7.08, and soil organic carbon 0.06-3.51%. Significant difference in salinity, the electrical conductivity of water and soil organic carbon was observed between the paddy fields. Precipitation, pH of soil and water correlated significantly with diversity of snails. Paddy fields, due to their unique ecological conditions and water holding capacity are suitable habitats for the snails. They are heterogeneous habitats providing space, shelter, and food for the survival of snails. Sustainable management of paddy fields is required to conserve the snail species associated with them.

**Keywords:** Snails, Karnataka, Abundance, Species richness, Management

Paddy fields are temporary man-managed wetlands, constitute 18% of the global wetlands. They are the unique agroecosystems and provide shelter for different aquatic organisms (Lawler 2001). Ecosystem services provided by paddy fields include production of non-rice foods, climate-change mitigation, groundwater recharge, flood control, soil erosion and landslide prevention, water purification, support other ecosystems and biodiversity (Natuhaara 2013). In India, two cropping seasons of rice are followed based on monsoon. The *kharif* cropping season is from June-October during the south west monsoon and the *rabi* crop is from November-March (winter). Paddy fields are the only ecosystems that come across aquatic, semi-aquatic and terrestrial phases during a single cultivation cycle. They experience wet phase during the cropping and dry phase at the end of cropping period. Paddy fields remain interconnected with each other through the ditches, water ways favours the growth of variety of fauna. Molluscs are the primary consumers in the food chain, help in nutrient cycling, and decomposition of organic matter thus enhancing the soil fertility (Stripari and Henry 2002, Jong Song et al 2018).

The studies that document the diversity of snails paddy fields of India and Karnataka state are limited (Gopalan et al 2014, Narasimhaiah et al 2014, Vineetha et al 2015,

Vineetha 2016). Environmental factors affecting the snail diversity of freshwater habitat areas are documented from different parts of the world (Nakanishi et al 2014, Bay and Park 2020). There are no adequate number of studies addressing the paddy field snail diversity of coastal Karnataka and factors governing the diversity of snails in paddy fields are not known. Although paddy fields are artificial wetlands the lack of knowledge on the patterns of species richness brings the urgent need for studies to provide scientific support to biodiversity management and conservation programs. Considering these points the study was designed to document the snail diversity in the paddy fields of coastal Karnataka.

## MATERIAL AND METHODS

Coastal Karnataka is the stretch of land along the Arabian Sea in the Karnataka state of India. It has an average width of 50-80 km and is surrounded by the Western Ghats and is known for the production of rice. To compare snail diversity between the paddy fields of coastal Karnataka six sampling sites were chosen (Table 1). Site selection was based on the number of crops, soil type (Sandy, muddy and clayey) and irrigated/non-irrigated paddy fields. Paddy fields at a distance of at least 20 km from each other were selected.

**Marlimar:** It is 3 km away from the city of Panemangaluru in the Malnad district of Dakshina Kannada. This site is 27 km away from the seashore and surrounded by arecanut plantations. Clayey type of soil is present. Aquatic plants such as *Eichornia*, *Hydrilla*, and *Chara* can be seen in this paddy field. This paddy field undergoes two cropping cycles *kharif* and *rabi*. *kharif* crops are cultivated at the onset of rainfall whereas *rabi* crop depends on irrigated water.

**Pavanje:** It lies on the border of Dakshina Kannada and Udupi districts. This paddy field is situated 1km away from the seashore and is composed of muddy and sandy soil. Aquatic weeds and grasses were observed during the study.

**Santoor:** This is present in the southern part of the Udupi district and a coal-based thermal power plant (Udupi Power Corporation Limited) is situated in this region. The paddy field selected for the study is 1.5 km away from the thermal power plant. The paddy field consists of clayey soil with fine particles. The cultivation of rice is entirely dependent on rainwater. Aquatic weeds, grasses, algae, and plants like *Pistia*, *Vallisneria* are found in the paddy fields.

**Mattu:** It lies towards the north of Santoor at a distance of 17 kms from Santoor and paddy fields are 250 m away from the seashore. These paddy fields are situated adjacent to the path of the Pangala river which joins the Arabian Sea. Soil is blackishly intermixed with sand particles. *Chara*, *Vallisneria*, and grasses were seen in this paddy field. Concretised earthen ditches were present in these paddy fields which help in the regulation of water flow to other paddy fields.

**Sastan:** It is situated in the northern region of the Udupi district. The selected paddy fields of Sastan are 2 km away from the seashore. The fields contain sandy and muddy soil and are surrounded by coconut plantations. A passage in the form of earthen ditches was found in this paddy field.

**Trasi:** It lies in the northern end of Udupi district and is 200 m away from the seashore. The paddy fields are composed of muddy soil combined with many sand particles. Paddy fields are situated nearer to national highway 66. Paddy cultivation in this site is entirely dependent on rainfall.

**Experimental details:** 10 kg of fertilizers will be used twice during the cropping in the paddy fields. Water inundation in

the paddy fields is the phase of inundating paddy fields with water before planting the crop till the end of the growth phase of paddy. It is generally started 15 days before the planting paddy and continued up to three months. The paddy field of Marlimar gets inundated with water for 6 months including both the cropping cycles whereas in other paddy fields water inundation takes place for 3 months.

**Sampling procedure:** The paddy fields were visited on monthly basis and the sampling was carried out in a *kharif* cropping season from June to October 2017, 2018. To check the presence or absence of snails after the first crop was documented by sampling in November 2017, 2018. The paddy field of Marlimar was visited during from June 2017-April 2018, June 2018-March 2019 for two cropping cycles whereas other paddy fields were visited during the first cropping cycle as only a single crop was in practice. During every sampling, 21 quadrates of 50cm×50cm were scattered in each paddy field randomly so that entire area of the paddy field at each site has an equal probability of sampling (Schoenly et al 2003). Snails were collected from each of the paddy fields and brought to the laboratory. Snails were preserved in 70% ethanol and identified using standard identification keys of Ramakrishna and Dey (2007). The abundance of snails is represented in the form of a percentage. Species richness is the number of species per quadrate.

Precipitation data of the study period was obtained from the Giovanni data system of NASA GES DISC. The paddy fields were visited between the interval of 8 A.M-11 A.M (IST) and 4 P.M-6 P.M (IST). The air temperature was measured in the field by holding the digital thermometer (SKU: TP-101 model, Ravi scientific industries) to air. Water temperature was measured by placing the digital thermometer inside the water samples. About 500 ml of water samples were collected from each paddy field and brought to the laboratory. Physico-chemical parameters of water such as electrical conductivity, pH and salinity have been analyzed in the laboratory (for 20 ml of water in each trial) using Systronics water analyzer 371 (Sripathy and Naveen Chandra 2014). About 0.5 kg of soil samples were collected from the paddy field, air-dried, powdered in the laboratory. Electrical conductivity, pH, and organic carbon of the soil were analyzed by standard protocols (Smith and Doran 1996).

**Statistical analysis:** Species diversity was calculated by the Shannon-Weiner index, species richness by Margalef's index, species evenness by Pielou's evenness index using PAST software version 2.17c. Shannon-Wiener diversity index (1949). Shannon-Wiener diversity index takes into account species richness and their evenness in an area. Shannon - Wiener diversity index  $H = - \sum p_i \ln(p_i)$  where  $p_i = S / N$

**Table 1.** Location of sampling sites in coastal Karnataka

Sampling sites	GPS location
Marlimar	12°51'58.51"N, 75° 3'35.27"E
Pavanje	13° 2'14.02"N, 74°47'32.82"E
Santoor	13° 09' 42"N, 74° 49' 27.3"E
Mattu	13°15'43.90"N, 74°43'52.56"E
Sastan	13°28'8.77"N, 74°42'46.18"E
Trasi	13°41'32.44"N, 74°38'48.17"E

S = number of individuals of one species

N = the total number of all individuals in the sample

ln = logarithm to base e.

Margalef's index =  $(S - 1) / \ln N$

S = total number of species, N = total number of individuals in the sample, ln = natural logarithm

The value ranges from 0-1, 0=least number of species, 1=highest number of species in a community. For calculating the evenness of species, the Pielou's Evenness Index (e) was calculated as.

$$e = H / \ln S$$

H = Shannon – Wiener diversity index, S = total number of species in the sample

Evenness refers to uniformity in species distribution. The evenness index ranges between 0-1, with 0 being no evenness and 1 being complete evenness.

Bray Kurtis similarity analysis was carried out using PAST software. As the data showed non normal distribution Kruskal-Wallis Test and Spearman correlation test were carried out. To find the significant differences if any, in species diversity and physicochemical parameters of soil and water between the sites, Kruskal-Wallis Test was performed. The influence of physicochemical parameters on snail abundance and species richness was studied using multivariate generalised linear model analysis. Relationship between species diversity and physicochemical parameters was determined by the Spearman correlation test. The data were analyzed statistically using SPSS version 21.

## RESULTS AND DISCUSSION

**Diversity and distribution of snails in paddy fields:** Five species of snails belonging to 5 families and 5 genera were observed from paddy fields of Udupi and Dakshina Kannada districts (Fig. 1). They are *Idiopoma dissimilis*, *Indoplanorbis exustus*, *Physella acuta*, *Pila virens* and *Racesina luteola*. *P. virens* is the pest of paddy, showed ubiquitous distribution (Table 2). *I. exustus* was more in number in most of the study sites. *P. acuta* (80%) was abundant in the paddy field of Marlimar and *P. virens* (45%) dominated in the paddy field of Pavanje.

Among the total number of individuals of snails collected from the rice field of Marlimar during the first cropping cycle, the abundance of snails increased from June and was at a peak in August in the years 2017 and 2018 (Table 3). Snail abundance was more in the rice field of Pavanje in July. On the contrary, the number of snails subsided in the fields of Santoor and Trasi from June to September. The number of snails declined in all the paddy fields during the reproductive phase of the paddy. The number of species increased from June to September and lessened towards the harvest (Fig. 2). Species richness was highest in the paddy field of Marlimar (Table 1). Species like *P. virens* and *I. exustus* were abundant in earthen ditches and found feeding on aquatic plants in paddy fields of Mattu, Trasi and Marlimar.

The changes occurred in snail diversity in paddy fields in November. Among the total number of snails collected in November 2017, abundance of snails was d in the paddy

**Table 2.** Distribution of snails in paddy fields of coastal Karnataka

Species	Family	Marlimar	Pavanje	Santoor	Sastan	Mattu	Trasi
<i>Idiopoma dissimilis</i>	Viviparidae	+	+	-	+	+	-
<i>Indoplanorbis exustus</i>	Planorbidae	+	+	+	+	+	+
<i>Physella acuta</i>	Physidae	+	-	-	-	-	-
<i>Pila virens</i>	Ampullaridae	+	+	+	+	+	+
<i>Racesina luteola</i>	Lymneidae	+	+	-	+	-	-

+ : Present, - : Absent

**Table 3.** Abundance of snails in the paddy fields during the first cropping period (%)

Location	2017					2018				
	June	July	August	September	October	June	July	August	September	October
Marlimar	4	15	40	35	2	2	4	60	35	1
Pavanje	10	75	8	3	0	38	10	20	20	15
Santoor	30	5	20	7	4	100	0	0	0	0
Mattu	35	5	3	0	0	1	5	80	10	0
Sastan	3	2	7	0	0	10	1	1	85	0
Trasi	8	0	5	5	5	60	2	3	1	5

fields of Sastan (72.22%) and Mattu (27.78%) as the paddy fields were filled with water. However, no snails were found in Pavanje, Santoor and Trasi. In November 2018, snails were not observed as the paddy fields remained dry. Among the total number of snails during the second cropping cycle abundance was higher in mid cropping cycle (January) and no snails were found during the end of cropping (April). Species richness of snails increased gradually from November, highest in of January and declined thereafter during the study (Fig. 3). *P. virens*, *P. acuta*, *R. luteola* and *I. dissimilis* were present. *P. acuta* was abundant in this paddy field during both the cropping cycles.

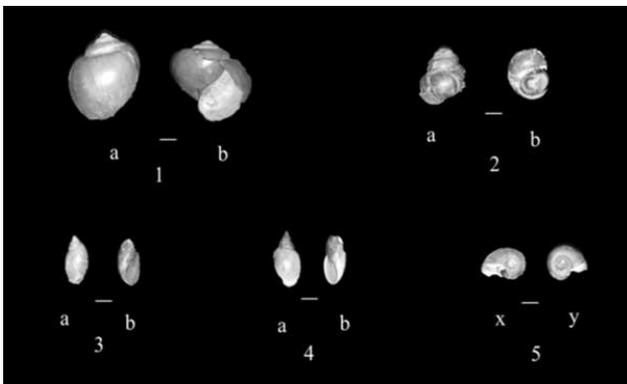
**Species diversity:** Highest Shannon diversity in Marlimar (1.47) and least for paddy fields of Mattu (0.53) during the first cropping cycle in 2017 (Table 4). Shannon diversity index was more in the paddy field of Pavanje, least in the paddy field of Trasi in 2018. Species diversity was higher in the paddy field of Marlimar during the first cropping cycle and declined during second cropping cycle. Diversity indices

were minimum in January as single species were abundant. Margalef's index was maximum in Marlimar (1.276) and Pavanje (0.983) in 2017 and 2018, respectively. The distribution of the snails was uneven in most of the paddy fields.

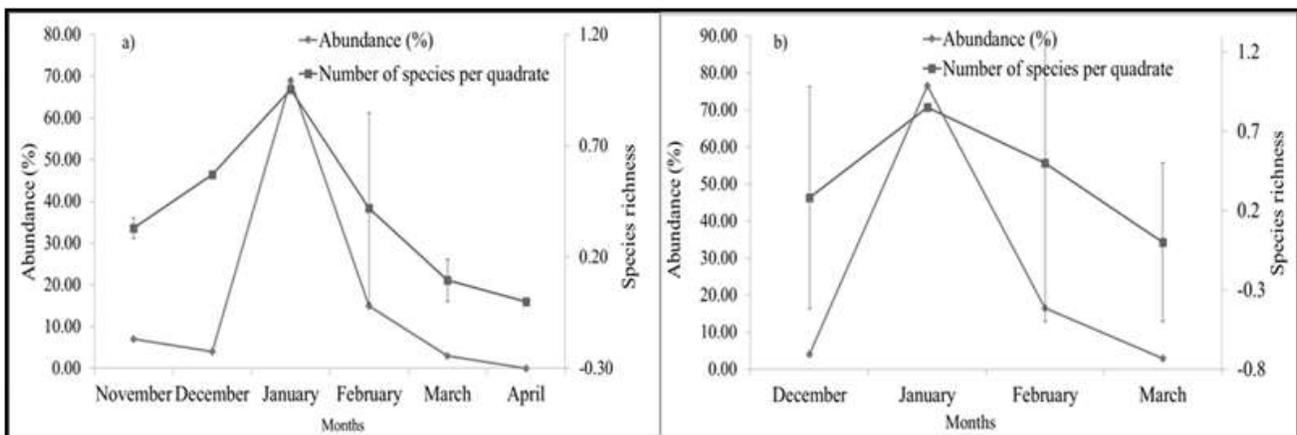
**Species composition of snails in the paddy fields:** The highest number of molluscan species were in the paddy field of Marlimar (5) followed by Sastan (4) and Pavanje (4). *P. virens* was abundant in the rice fields of Pavanje, Santoor, and Trasi. *I. exustus* was dominant in the rice fields of Mattu (75%) and Sastan (55%) whereas *P. acuta* dominated (80%) the rice field of Marlimar (Fig. 4).

Bray Kurtis similarity index of 1 means that the two communities used for the comparison share all their species, while a value of 0 means they share none. Paddy fields of Santoor and Trasi formed a cluster indicating that they are ecologically similar in terms of the number of species. Paddy fields of Pavanje and Sastan formed a cluster with a Bray-Curtis similarity index of 0.5, which joined with the paddy field of Mattu to form a supercluster (Fig. 5). The paddy field of Marlimar with different species composition was dissimilar to other paddy fields thus forming a separate cluster. The clusters joined with a widely separated cluster of Marlimar denoting the least similarity.

**Climatic conditions and physicochemical parameters of soil and water in the rice:** Precipitation was the variable selected to understand the climatic conditions of the paddy fields. Precipitation ranged between 0.48mm-774.2mm. The highest and least values of precipitation were in July 2018 and January 2018 respectively. There was an increase in species richness with the increase in precipitation during the study. Water temperature and air temperature varied between 25.5°C-36.1°C and 25°C-35.4°C respectively. The temperature of air and water declined at the onset of the monsoon and increased towards the end. The abundance of



**Fig. 1.** Snails found in paddy fields of coastal Karnataka. 1. *P. virens* 2. *I. dissimilis* 3. *R. luteola* 4. *P. acuta* 5. *I. exustus* a: Apertural views b: Apertural views x: Apical view. y: Basal view; Scale bar: 8 mm



**Fig. 2.** Abundance and species richness (Mean ± Standard deviation) of snails in paddy field of Marlimar during second cropping cycle for the period (a) 2017-2018 and (b) 2018-2019

snails lessened when the water temperature was above 32°C. The electrical conductivity of water ranged from 3.89-1136 µS/m during the study. Maximum values of electrical conductivity were recorded from the paddy field of Marlimar during the second cropping cycle.

The pH of water varied from 3.4-8.53 in the paddy fields. The highest pH was in Marlimar during the second cropping cycle. The abundance of *P. acuta* in the rice field of Marlimar was observed when the pH of the water was between 6-7. The salinity of water ranged between 0-0.9 ppt. Maximum salinity was observed in paddy field of Pavanje. The values increased towards the end of the cropping period with the reduced rainfall. Soil pH was in the range of 3.07-7.08. Soil pH was maximum in the paddy field of Pavanje (7.08) and minimum in Santoor (3.07). The electrical conductivity of the soil varied from 0.01-0.85µS/m. The highest and least were from Mattu in November 2017 and September 2018. Organic carbon of the soil ranged between 0.06-3.51%. Maximum values of organic carbon were recorded from the paddy field of Marlimar (3.510) during the second cropping cycle.

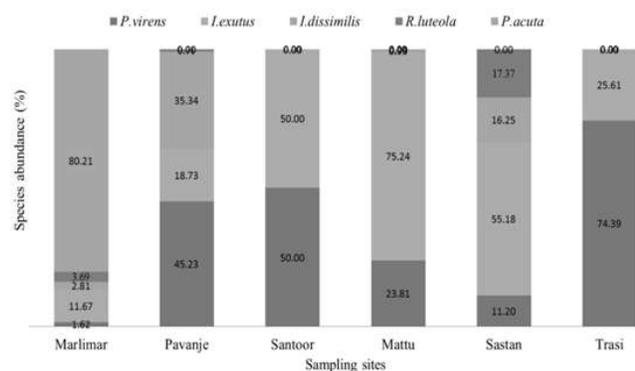


Fig. 4. Distribution of snails in paddy fields of coastal Karnataka

Kruskal-Wallis test revealed that there is a significant difference in salinity ( $P=0.002$ ), the electrical conductivity of water ( $P=0.019$ ), and organic carbon of the soil ( $P=0.001$ ). However, the abundance and species richness of snails did not vary significantly between the sites (Table 5). When species richness was considered as the dependent variable and the data was analysed using multivariate generalised linear model analysis the independent variable soil pH differed significantly suggesting that the soil pH significantly predicted richness (Table 6). Other independent variables are not statistically significant.

Multivariate generalised linear model analysis showed that the independent variable pH of water differs significantly when abundance was the dependent variable (Table 7).

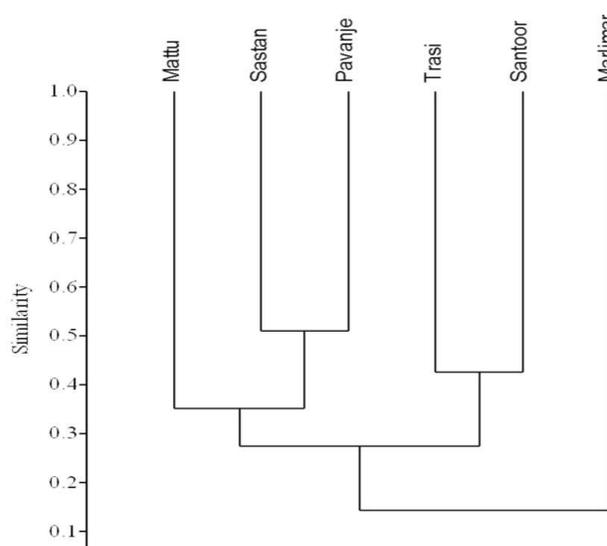


Fig. 5. Bray-Curtis similarity analysis for the paddy fields studied

Table 4. Diversity indices in the paddy fields during the first cropping cycle

Diversity indices	Marlimar		Pavanje		Santoor		Mattu		Sastan		Trasi	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
H'	1.470	0.616	0.827	1.076	0.674	0.495	0.532	0.685	0.983	0.723	0.679	0.000
R	1.276	0.620	0.589	0.983	0.703	0.500	0.510	0.497	0.678	0.602	0.750	0.000
J'	0.870	0.463	0.762	0.733	0.981	0.820	0.567	0.992	0.891	0.686	0.986	1.000

H'=Shannon Weiner Index, R=Margalef's Index; J'=Evenness Index

Table 5. Kruskal-Wallis test to check the variations in species diversity and physicochemical parameters of the paddy fields

	Abundance	SR	AT	WT	Salinity	EC of water	pH of water	Soil pH	Soil EC	SOC
Chi-Square	9.854	10.744	6.183	4.235	18.658	13.563	7.892	0.703	7.804	26.176
Significance	0.079	0.057	0.289	0.516	0.002	0.019	0.162	0.084	0.167	0.001

\* SR= Species richness, AT = Air temperature, WT = Water temperature, SOC=Soil Organic Carbon, EC=Electrical conductivity

Other independent variables are not statistically significant. It is evident that pH of water significantly predicted abundance. When Spearman correlation was carried out, significant positive correlation was observed between abundance and pH of water, species richness and pH of water, soil pH and abundance, soil pH and species richness, salinity and electrical conductivity, salinity and pH of water, air temperature and water. Precipitation correlated significantly with species richness of snails. However, air temperature, water temperature, salinity, the electrical conductivity of water, soil conductivity, and soil organic carbon did not correlate significantly with the abundance and species richness of snails (Table 8).

The diversity of snails in paddy fields of coastal Karnataka was studied and 5 species of snails were documented. Of these, *P. virens* and *I. exustus* were in most of the paddy fields. These species have been reported by Narasimhaih et al (2014) from the paddy fields of Mangalore of coastal

Karnataka and suggested that the climatic conditions including water and soil influence the survival of the snails. The population of *I. exustus* was more in the paddy fields of Marlimar, Pavanje and Mattu than the other paddy fields. This could be attributed to the availability of aquatic macrophytes. Molozzi et al. (2007) showed that the vegetative parts of aquatic macrophytes supply oxygen for the survival of snails. Aquatic macrophytes are food for snails and help in deposition of egg masses (Galan et al 2015). The spawning capacity of *I. exustus* and the ability to colonize varied habitats are the key factors that determine its presence in the paddy fields (Chantima et al 2018).

During the study, the number of species was highest in the paddy field of Marlimar which may be due to the water inundation and availability of habitable areas for the snails. In the present study, during the wet period (Beginning of cropping cycle) the number of snails started to increase and highest during the middle of the cropping when rainfall was

**Table 6.** Multivariate generalised linear model analysis for physicochemical parameters influencing species richness of snails between the sites

Parameter	Regression coefficient (B)	Std. error	95% Wald confidence interval		Hypothesis Test	
			Lower	Upper	Wald Chi-Square	P
Air temperature (°c)	-0.034	0.035	-0.103	0.035	0.916	0.339
Water temperature (°c)	0.029	0.030	-0.031	0.089	0.927	0.336
Salinity (ppt)	-0.027	0.019	-0.064	0.011	1.956	0.162
Electrical conductivity (µS/m)	0.000	0.000	-0.001	0.000	0.481	0.488
pH of water	0.119	0.047	0.026	0.211	6.351	0.012
Soil pH	-0.230	0.230	-0.681	0.221	0.996	0.318
Soil conductivity (µS/m)	-28.763	202.58	-425.83	368.30	0.020	0.887
Organic carbon (%)						

Dependent Variable: Species richness

Model (Intercept) Air temperature, Water temperature, Salinity, Conductivity, pH of water, Soil pH, Soil conductivity, Organic carbon

**Table 7.** Multivariate generalised linear model analysis to know the physicochemical parameters influencing species abundance of snails between the sites

Parameter	Regression coefficient (B)	Std. error	95% Wald confidence interval		Hypothesis Test	
			Lower	Upper	Wald Chi-Square	P
Air temperature (°c)	-0.319	0.250	-0.810	0.173	1.617	0.204
Water temperature (°c)	0.034	0.217	-0.392	0.461	0.025	0.874
Salinity (ppt)	-0.086	0.135	-0.351	0.179	0.405	0.525
Electrical conductivity (µS/m)	-0.001	0.001	-0.004	0.003	0.092	0.762
pH of water	0.862	0.344	0.188	1.536	6.278	0.012
Soil pH	0.333	0.335	-0.325	0.991	0.982	0.322
Soil conductivity(µS/m)	-2.062	1.638	-5.273	1.148	1.585	0.208
Organic carbon (%)	-1054.42	1441.035	-3878.79	1769.95	0.535	0.464

Dependent Variable: Abundance

Model: (Intercept), Air temperature, Water temperature, Salinity, Electrical conductivity, pH of water, Soil pH, Soil conductivity, Organic carbon

**Table 8.** Spearman correlation of abundance and species richness of snails with physicochemical parameters of soil and water (N=81)

	Abundance	SR	P	AT	WT	Salinity	EC of water	pH of water	Soil pH	Soil EC	SOC
Abundance	1.000										
SR	0.935**	1.000									
P	0.333	0.516**	1.000								
AT	-0.132	-0.128	NA	1.000							
WT	-0.082	-0.036	NA	0.585**	1.000						
Salinity	0.137	0.003	NA	0.239 <sup>†</sup>	-0.119	1.000					
EC of water	-0.007	-0.078	NA	0.079	-0.131	0.681**	1.000				
pH of water	0.257 <sup>†</sup>	0.243 <sup>†</sup>	NA	0.056	0.203	0.292 <sup>†</sup>	0.203	1.000			
Soil pH	0.422**	0.434**	NA	-0.216	0.047	0.050	-0.052	0.047	1.000		
Soil EC	-0.680	-0.071	NA	-0.208	-0.051	-0.145	-0.073	0.142	-0.013	1.000	
SOC	0.021	0.003	NA	0.129	0.037	0.191	0.416**	0.050	-0.052	0.015	1.000

<sup>†</sup>AT=Air temperature, WT=Water temperature, P=Precipitation, SR=Species richness, EC=Electrical conductivity, SOC=Soil Organic Carbon, NA=Not applicable. \*, \*\*. Correlation is significant at the 0.05 and 0.01 level (2-tailed).

maximum and paddy fields were filled to the maximum extent. During the dry period (Harvest) the snails burrow in the soil due to inadequate soil moisture. The paddy field of Marlimar undergoes two cropping cycles and gets inundated with water for about 6 months. This inundation period may be a reason for the species richness of snails in the paddy field. Moreover, paddy field of Marlimar has a different species composition than the other paddy fields may be due to the clayey soil which can hold more water whereas rice fields such as Sastan and Trasi comprising of sandy soil have poor water holding capacity. In addition, the paddy field of Marlimar differs from other paddy fields as it is located 27 km away from the sea, which contributes to more species diversity. The abundance of *P. acuta* in the paddy field of Marlimar was observed which may be attributed to a higher rate of fecundity (Saha et al. 2016). The environmental conditions of the paddy fields form the unique habitats for molluscs (Vineetha 2016). The ecological conditions of the paddy field of Marlimar may have helped in the growth and reproduction of *P. acuta*. Since irrigation provides moisture for the snails to thrive in the paddy fields may be one of the reasons for species richness in the irrigated paddy fields. Irrigation cannot be the only reason for more species diversity in the study sites. The ecological conditions of the paddy field of Marlimar are unique from the other paddy fields and provide good habitats.

Species abundance and richness were similar in the paddy fields of Sastan and Pavanje, but dissimilar to other paddy fields. Similar ecological conditions and soil types in the paddy fields of Sastan and Pavanje may be the reason for this. Less diversity of molluscs in the paddy fields of Santoor, Mattu, and Trasi could be because of the unfavourable environmental conditions existing in this site such as an

increase in air temperature and water temperature, variations in pH sandy, and muddy soil, and lesser period of water. Lawler (2001) opined that the paddy fields inundated with water for a longer period will have more species.

The increase in the number of snails from June to August was observed, which is ascribed to a higher rate of decomposition in the rice fields in the initial stages of cultivation that favoured the growth of snails (Vineetha et al. 2015). The abundance of the snails was observed in the middle of the second cropping cycle. The paddy field of Marlimar will be subjected to two cropping cycles and the fertilizers applications in November (first cropping) and in January (second cropping) will be used twice during the cropping period in these sites and water is supplied through irrigation. The decrease in the number of snails in the paddy fields during the reproductive phase of paddy may be because of the decrease in rainfall and less decomposition in the paddy fields. The shades of larger plants reduce the rate of decomposition and prevent sunlight penetration into the fields (Bambaradeniya and Amerasinghe 2004). Eventually, the snail population lessens due to the unavailability of decomposed matter. Besides, the paddy fields get occupied by the roots of the paddy, reducing the area for the growth of molluscs (Ojha et al. 2010). Previous studies from the Kerala state of India have shown the abundance of snails in paddy fields and suggested that the presence of aquatic plants is conducive to the abundance of snails and other invertebrates (Gopalan et al. 2014). The snail species survive in the paddy fields by resource partitioning i.e. by hiding under paddy straw, under the roots, within the soil and feeding the debris on the water, thus paddy fields act as suitable habitats for snails (Ojha et al 2010).

When water temperature was above 32°C number of snails declined. Mortality of Ampullarids above this temperature has been reported Cowie (2001). The electrical conductivity of water varied during the study which could be due to inflow of water, nutrient cycling and fertilizer application (Stevens et al 2006). Organic carbon of the soil increased with the progress of monsoon, could be due to the decay of aquatic macrophytes. Maximum organic carbon was recorded in the growth phase of paddy during the second cropping cycle that could be attributed to increased carbon input to the soil due to fertilizer applications (WeiGong et al 2012). Organic carbon enhances water retaining capacity of the paddy soil (Rawls et al 2003) thus helping in survival of snails.

The present study suggests that diversity of snails in the rice fields is mainly dependent on monsoon and presence of water in post-monsoon. Besides, ecological conditions of paddy fields favour the abundance of snail species. Inundating rice fields with water after monsoon would help the many snail species to thrive in these manmade wetlands thus productivity can be enhanced.

### CONCLUSIONS

The present study focused on the ecology of the paddy fields of coastal Karnataka and the number of snails found in these wetlands during the cropping period. Paddy fields of coastal Karnataka incorporate a variety of snail species are the unique ecological niches for their survival. Snail diversity increases with the onset of monsoon and during irrigation but declines as the water evaporates during summer. The water holding capacity of paddy fields and presence of earthen ditches determine the number of snails. Rainfall, pH of water and soil influences the species richness of the snails in the paddy fields. Snail species meeting the optimum pH conditions of the paddy fields survive in such habitats, however, the physicochemical parameters of water and soil along with the environmental variables have a cumulative effect on the diversity of snails. Paddy fields of coastal Karnataka are being lost because of rapid urbanization. Perhaps the loss of habitat for snails in the paddies is offset by the presence of space, microhabitats, connectivity between the paddy fields and earthen ditches. As the paddy fields of coastal Karnataka, are disappearing due to land use for developmental activities, paddy cultivation throughout the year with an improved water supply and conversion of barren lands into paddy fields would help to sustain and nourish the snail diversity of these wetlands.

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